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Improved Maintenance Management for Army Central Energy Plants

by
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One important way for the U.S. Army to reduce installation operating costs is to improve maintenance operations and management practices at central energy facilities. Significant monetary savings and improvements in overall operating efficiency can be achieved by implementing a preventive or predictive maintenance program. The benefits are realized in the form of improved plant efficiency, lower maintenance costs, and less downtime. When an improved maintenance program is properly established and supported, the benefits can continue indefinitely in the form of hard savings.

This report provides an overview of methods and tools available to Army central energy plant managers for improving maintenance operations and management, and offers guidelines for comparing the cost-effectiveness of different approaches.

It is shown that most Army central energy plants could meet a 5-year payback deadline by implementing a preventive maintenance program. Many Army facilities could also expect a 5-year payback on a predictive maintenance program, even though the startup costs are greater.

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Foreword

This study was conducted for U.S. Army Center for Public Works (USACPW) under Project 4A162784AT45, "Energy and Energy Conservation"; Work Unit EB-XK3, "Central Energy Supply: Advanced Operations and Maintenance." The technical monitor was Satish Sharma, CECPW-EM.

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1 Introduction

Background

One important way for the U.S. Army to reduce installation operating costs is to improve maintenance operations and management practices at central energy facilities. Significant monetary savings and improvements in overall operating efficiency can be achieved by implementing an improved approach to maintenance operations and management. These benefits are realized in the form of improved plant efficiency, lower maintenance costs, and less downtime. When an improved maintenance program is properly established and supported, the benefits can continue indefinitely in the form of hard savings.

All machines eventually break down. The term *machine maintenance* generally refers to the process of preventing breakdowns and repairing them. The responsibility for machine maintenance is usually assigned to a staff of specially trained personnel. Machine maintenance has traditionally been performed mostly on a "hit or miss" basis, often only when a machine is broken or out of service. This traditional maintenance philosophy, known as the *run-to-failure* approach, has told generations of maintenance workers, "If it ain't broke, don't fix it." Run-to-failure may have been an acceptable maintenance philosophy in earlier times, but current standards of reliability and efficiency require a more advanced approach. This is especially true of the U.S. Army's central energy facilities, many of which provide critical service to Army installations or industrial facilities.

There are two major drawbacks to run-to-failure maintenance. First, it is unlikely that a maintenance person is capable of predicting exactly when a machine is going to break down, without specialized equipment or training. By definition, a machine may fail at any time under the run-to-failure approach. When machine failure occurs during peak demand, the economic and productivity issues can be serious. For example, an Army food processing plant served by a small power facility can be completely disabled if key power facility machinery fails catastrophically during a hot spell; the food processing plant becomes unable to fulfill its mission, and significant out-of-pocket losses may result from spoilage of refrigerated product.

The second major drawback of run-to-failure maintenance is the scope of damage resulting from catastrophic failures. Not only is the failed machine severely damaged or destroyed, but associated machines can also be damaged. This related machine damage not only leads to higher repair costs, but also causes extra downtime.

Despite these drawbacks, many Army central energy facilities continue to use this approach. The resistance to change may stem from a fear of new methods or technologies, but it may come from the misconception that an improved maintenance program will cost more money and require more personnel. The opposite is true, however: a well established and well managed maintenance program usually produces significant savings.

In a very small facility, an improved maintenance program may not be cost-effective—but that is the exception, not the rule. In most cases, an improved approach to maintenance operations and management will pay off in terms of more effective use of maintenance and repair (M&R) resources.

Objectives

The objectives of this report are (1) to provide an overview of methods and tools for improving maintenance operations and management at Army central energy facilities, and (2) to offer guidelines for comparing the cost-effectiveness of different approaches.

Approach

A literature search was conducted to collect the information most applicable to Army central energy plants, and to identify commercial vendors of maintenance improvement technology. The findings of the literature search were combined with the authors' professional knowledge of energy plants to create an outline for implementing an improved maintenance program. Finally, guidelines for evaluating the economics of these programs for various sizes and types of Army energy plants were compiled.

Mode of Technology Transfer

Technology transfer will be conducted through field demonstrations and support. Dissemination of this information in a Public Works Technical Bulletin, *CPW Digest* articles, and USACERL information exchange bulletins is also recommended.

2 Review of Alternative Maintenance Approaches

This chapter discusses the advantages and disadvantages of run-to-failure, preventive maintenance, and predictive maintenance.

Run-to-Failure

As noted in Chapter 1, run-to-failure means operating machinery until it breaks down. Only after breakdown are corrective measures taken—repair or replacement are the only options. This approach is still commonly practiced both in Army and private-sector industrial facilities.

Advantage

Run-to-failure essentially has no direct advantage over more sophisticated approaches. Indirectly, it might be considered to have an advantage in that it is the easiest method for many facilities to continue using. Continuing with the run-to-failure approach avoids the immediate costs of retraining personnel and other related up-front costs. While this advantage may be important in select cases, run-to-failure has serious disadvantages.

Disadvantages

Because there is no advanced warning of failure under the run-to-failure approach, any resulting failures are catastrophic. (In this context, *catastrophic* means complete failure—total machine breakdown.) When failure is catastrophic, the damage frequently affects nearby or connecting machines. Furthermore, catastrophic failure generally maximizes machine damage. The result is higher repair costs.

Another disadvantage is that failure may occur at any time, including times of highest demand. The untimeliness of such failures further aggravates the losses caused by machine downtime. Because of the lack of warning prior to failure, all repairs are, by definition, emergency repairs. These often require hours of overtime work by the maintenance staff or outside contractors, adding even more to the costs of run-to-failure.

Another problem related to the inherent untimeliness of catastrophic failure is that it is almost impossible to have every necessary repair part and tool on hand when a machine fails. This logistical problem further increases the amount of downtime required for the repair process.

Catastrophic failure also poses a significant safety risk: personnel near a failing machine are in greater risk of injury.

Finally, because the machine is operated right up until the time of failure, it can be inferred that the machine has been operating in a damaged state for some time. The damaged machine may have been producing an inferior product or unnecessarily high amounts of scrap. In the case of an energy facility, machinery operation will be less efficient, leading to higher energy consumption.

The drawbacks listed above are not the only disadvantages of run-to-failure, but they strongly indicate that an improved maintenance program is desirable.

Preventive Maintenance

Preventive maintenance is the practice of prescheduling maintenance procedures to reduce the likelihood of catastrophic failures. Preventive maintenance tasks are performed on schedule whether the machines appear to need them or not. Some catastrophic failures will still occur under a preventive maintenance program, leading to the need for emergency repairs. However, because most catastrophic failures are avoided, there are many advantages to implementing a preventive maintenance program.

Advantages

Preventive maintenance reduces the amount of production downtime because machine breakdowns are less frequent. Implementation of a preventive maintenance program may reduce downtime from 50 to 80 percent.

Another benefit is lower expenses for overtime pay, because emergency repairs are required less frequently. A comprehensive preventive maintenance program may save as much as 90 percent on overtime pay.

Improved product quality with less waste is a third benefit. A comprehensive preventive maintenance program may reduce scrap (or inefficiency) by as much as 30 percent.

A fourth benefit is an increase in equipment life expectancy. A good preventive maintenance program can extend the life of equipment to the point of reducing capital spending by 10 to 20 percent.

Reduced maintenance costs is a fifth benefit. A good preventive maintenance program may reduce labor costs by as much as 10 percent, and reduce material costs by as much as 30 percent. Preventive maintenance can also lead to a smaller inventory of replacement parts or equipment, which reduces the need for storage space and reduces the amount of money that needs to be budgeted for these excess materials.

Finally, a good preventive maintenance program enhances employee safety, reducing worker compensation and insurance costs.

Despite this impressive list of advantages, there are two significant problems with implementing a preventive maintenance program.

Disadvantages

Information about machine condition is obtained only during implementation of a preventive maintenance program, so machines are still likely to experience occasional catastrophic failure—but less often than under run-to-failure. Also, a considerable amount of downtime is required to complete all scheduled maintenance tasks. While the amount of downtime required for preventive maintenance is less than the time lost to catastrophic failures under run-to-failure, scheduled downtime can still have a significant impact on plant productivity.

Predictive Maintenance

Predictive maintenance is the practice of periodically monitoring machinery with some form of instrumentation to predict forthcoming machine failures. This approach makes it possible to schedule appropriate maintenance procedures before an actual failure. It also allows for the acquisition of all necessary tools and materials before a machine is shut down for repairs, which reduces machine downtime. It should be noted that predictive maintenance includes some of the same steps as preventive maintenance, such as periodic oil changes.

Some of the different types of instruments used for predictive maintenance include:

- vibration analyzers
- stress analyzers
- leak detectors
- oil analyzers
- thickness gages
- infrared and thermal imaging devices.

Vibration analyzers are the most useful tools for predictive maintenance of much energy-plant equipment, especially for pumps, fans, motors, turbines, blowers, and chillers. Other tools listed above also have useful power-plant applications, but do not appear to be as cost effective as vibration analyzers. Some special applications may merit the purchase of some of this additional equipment.

Advantages

The advantages of a predictive maintenance program are the same as those of a preventive maintenance program, but to a greater degree. All savings on labor, materials, insurance, etc., are greater because predictive maintenance is more efficient. Because all machines are monitored periodically, maintenance is performed only on those machines that need it, eliminating some of the redundant or unnecessary tasks automatically scheduled under a preventive maintenance program. The elimination of unnecessary tasks will reduce downtime compared to preventive maintenance, promoting even greater operating efficiency.

Although predictive maintenance is the most advanced approach to machine maintenance, this approach does have some drawbacks.

Disadvantages

Predictive maintenance cannot identify all problems before a machine fails. Frequency of monitoring, material quality, maintenance workmanship, and other factors can all lead to deficiencies in a predictive maintenance program.

Because some information needed to establish and operate a predictive maintenance program may not be common knowledge, some training of personnel is essential to ensure a successful program. Although most vendors of vibration-analysis packages offer user training, additional training may be required. Upon implementation of a good predictive maintenance program in an appropriate environment, however, the long-term benefits will far outweigh the costs and inconveniences of initial startup and training.

Figure 1 illustrates relative amounts of downtime required for run-to-failure, preventive, and predictive maintenance.

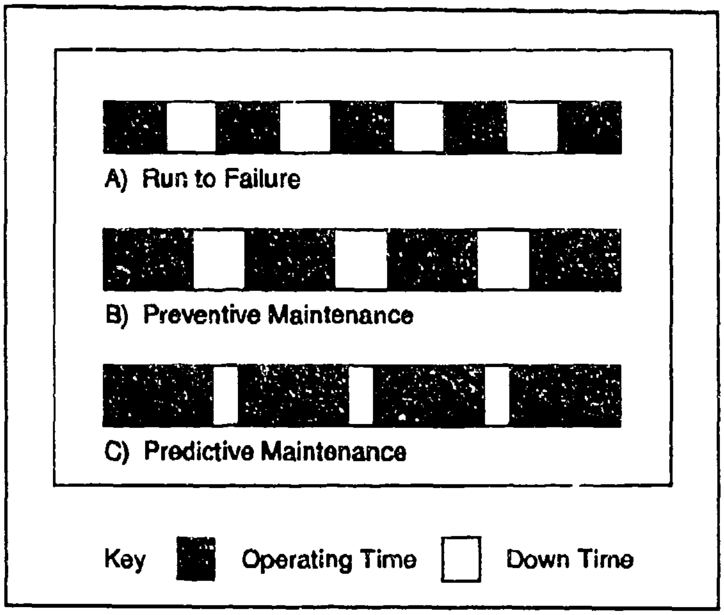

Figure 1. Downtime comparison for three maintenance approaches.

3 Implementation of an Improved Maintenance Program

After plant managers and personnel decide which maintenance program best suits their particular facility, the next step is implementation. A half-hearted attempt at implementation will not be very satisfactory. In fact, a poorly implemented maintenance program may impede proper maintenance operations, and end up being counter-productive.

Implementing Run-to-Failure

Run-to-failure is the easiest program to implement because it requires no up-front effort. No new procedures are required for a run-to-failure program because no corrective actions are taken until a machine fails. For energy facilities, run-to-failure should not be considered a viable option.

Implementing Preventive Maintenance

Implementing a preventive maintenance program requires several steps. Failure to properly address all steps can make the program ineffective.

Step 1 is to develop a plan for implementation and operation of the program. The plan should outline what to do and how to accomplish it. Without this plan, there is no way to confirm whether the program is meeting its intended objectives.

Step 2 is to inventory all machinery to be covered under the program. This inventory should include all information that will help determine exactly which maintenance tasks should be performed on which machines, and how often. Typical information should include:

- type of machine
- list of components on each machine
- age of machine

- condition of machine
- work and maintenance history of machine.

Step 3 is to create the preventive maintenance taskings. Using the information gathered in Step 2, a list of maintenance tasks for each machine is developed, as well as a schedule for task frequency (e.g., daily, weekly, monthly, runtime hours). Other information to document at this time includes:

- skill designation for each task
- time required to perform each task
- tools required to complete each task
- materials required to complete each task.

After the required labor and materials are known for each individual task, a comprehensive resource list should be prepared. This master list should show exactly how much time is needed to perform all preventive maintenance tasks, and should document tools and materials necessary. However, the master list should not include any labor or materials necessary to perform emergency maintenance tasks.

Step 4 is to schedule the actual calendar dates for each maintenance task.

To optimize worker productivity on these tasks, the following three procedures will help:

1. After shutting down a machine for preventive maintenance, perform all tasks at that time. Frequent machine shutdowns negate some of the efficiency gained through preventive maintenance.
2. When performing preventive maintenance at a remote part of a facility, try to schedule as much work in that area as possible to reduce travel time.
3. Make sure maintenance personnel are equipped with all tools and materials required to complete their assigned tasks *before* they begin the job. Much time can be wasted running back and forth after tools and materials.

Step 5 may be the most important. After the plan is developed and approved, maintenance personnel must be trained to handle any new procedures or equipment used in the program. Most failures of preventive maintenance programs result from an undertrained staff.

Implementing Predictive Maintenance

Due to the similarity between preventive maintenance and predictive maintenance, the outline for implementing preventive maintenance should also be used to implement a predictive maintenance program. There is one important difference, however: instead of scheduling all maintenance tasks on the *calendar*, predictive maintenance tasks are scheduled according to *need*, as determined by machine monitoring.

Four different approaches to running a predictive maintenance program are possible.

Vibration Meters

The first approach is based on the use of a vibration meter. Vibration meters cost considerably less than vibration analyzers (see next paragraph), and they provide much less information. But these devices are very useful as alarms to notify the user of worsening vibration before a failure. They do not provide any information about the cause of the vibration, so the exact problem must be identified and analyzed by a skilled maintenance technician, who must then propose an effective solution. The main advantage of vibration meters is that they cost less up front than vibration analyzers while still providing important benefits. In plants whose equipment is maintained by contractors, vibration meters are also useful for quality assurance. By taking a few simple vibration readings, in-house personnel can verify the quality of equipment installation and maintenance. If a machine is discovered to vibrate excessively, the contractor can be notified and required to fix the problem.

Vibration Analyzers

The second approach to setting up a predictive maintenance program is based on the use of a vibration analyzer, and includes appropriate training for personnel administering the program. This training, which is offered by several analyzer manufacturers, teaches the employee to read and interpret the plots generated from the data collected with the analyzer. These abilities enable personnel to predict what kind of failures may occur, and to recommend the best solution for the problem. Associated software can help the technician find problems so data plots can be analyzed to predict the specific nature of the upcoming failure. One example is to use broadband analysis, in which alarms on each machine are set off when vibration exceeds a predetermined threshold. When the threshold is exceeded, the software produces a report confirming high levels of vibration. The technician can retrieve the graphs for that machine and predict the probable cause of the vibration, and schedule the proper actions to correct the problem. With the correct training and a little experience, the personnel can excel at predicting the trouble areas. The Appendix lists several organizations that offer training in data analysis.

This approach is strongly recommended because it requires training that will give the technician an understanding of the predictive maintenance process. This understanding will be valuable later in making decisions about when and how to upgrade the system.

Vibration Analyzers Supplemented by Expert Systems

The third approach to setting up a predictive maintenance program includes a vibration analyzer used in conjunction with a computer-based expert system. The technician takes data readings from the equipment, as in the approach described in the two previous paragraphs, but when the readings are downloaded to the computer, the expert system software automatically analyzes the data and produces reports on all equipment from which readings were taken.

This approach represents the current state of the art technologically, but it does not require the technician to understand vibration analysis technology or interpret its outputs. Consequently, the technician has less value to add under this approach. However, a facility can start with the second approach, then add the expert system after the predictive maintenance program is well established and understood by personnel. A big advantage of such a two-tiered approach is postponement of the out-of-pocket expenses for acquiring and setting up the expert system. With the second approach, a facility can start a predictive maintenance program and later expand into the third approach, without initially investing in an expensive expert system. Another advantage, as noted in the previous section, is that technicians will have received training in vibration analysis technology and predictive maintenance by the time the expert system is implemented. This training will allow the technicians to bring their own expertise to work alongside the outputs of the computer-based expert system.

Predictive Maintenance by Contract

The fourth approach to setting up a predictive maintenance program is to contract with a qualified company to provide all predictive maintenance services. While this approach has the advantage of saving on initial startup costs, it would ultimately cost most plants much more than the other three approaches throughout the facility's life cycle.

Because the second option is considered the best approach to predictive maintenance for Army central energy plants, this report focuses primarily on topics associated with this option.

The details of implementing and operating a predictive maintenance program are described in USACERL Technical Report FE-93/25, *Vibration Monitoring for Predictive Maintenance in Central Energy Plants* (Moshage and Bowman, September 1993). This report explains how vibration analyzers work, summarizes operating procedures, identifies the types of problems vibration analysis can detect, and compares several typical vibration analyzers currently on the market. The report's appendices include techniques for solving some of the more common problems that can be identified through vibration analysis.

Economic Guidelines For Selecting an Improved Maintenance Program

To determine which type of maintenance program best suits the needs of an individual facility, a brief look at potential savings versus costs will usually make the choice clear.

As previously noted, only the smallest facilities can justify continuing with a run-to-failure program—and only if there is no critical machinery in that facility. It was also noted that run-to-failure should *not* be used in Army energy facilities of any size.

The following paragraphs present examples of potential savings for three Army heating facilities of different size. The potential savings are calculated using only the reduction in maintenance costs (i.e., 10 percent savings on labor and 30 percent savings on materials) discussed in Chapter 2, noting that 35 percent of all maintenance costs can be attributed to rotating equipment such as motors. Additional savings could be expected if the other advantages of improved maintenance were considered (e.g., downtime, emergency repair costs, etc.). The cost statistics for each plant were obtained by CECPW-SS-C, U.S. Army Center for Public Works (USACPW). (It should also be noted that these statistics include boilers and heaters with an output capacity of 750,000 Btu/hr or higher.)

Because these statistics apply to facilities that use smaller boilers and heaters, the information in Table 1 may also be used by managers of small non-Army industrial facilities to estimate potential savings of predictive maintenance for their own plants. If a cost analysis was computed Army-wide, the potential savings would reach millions of dollars. For plant personnel to determine which type of maintenance program is most cost-effective for a given facility, a comparison similar to the examples in Table 1 can be made.

The examples in Table 1 show that only for the smallest plants may predictive maintenance not prove cost-effective. Assuming a payback period of 5 years, only Plant 3 might consider using something less than a predictive maintenance program, because the payback after 5 years would not add up to the original $18,000 outlay. But before selecting something other than predictive maintenance based solely on the payback numbers, full consideration should be given to all the advantages outlined in Chapter 2. Furthermore, if Plant 3 operates any machinery critical to plant operations, a predictive maintenance program may be advisable even if it does not appear to be cost-effective.

It should be noted that even Plant 3 could meet a 5-year payback deadline if it used a scaled-down predictive maintenance program. This would involve collecting data with a vibration meter or a scaled-down version of a vibration analyzer. While the overall effectiveness of a scaled-down program would be reduced, so would the initial costs. Also, the potential savings outlined in Chapter 2 are based solely upon the implementation of a preventive maintenance program, so the savings would still apply when a preventive maintenance program is supplemented with a vibration meter or any other element of a predictive maintenance program.

Because no special equipment is required to implement or operate a preventive maintenance program, the only out-of-pocket costs arise from the time spent to initiate the program. The amount of time required will depend on plant size and complexity. Therefore, no generic cost formula applies to all plants, so the out-of-pocket costs for implementing preventive maintenance should be calculated on a plant-by-plant basis. Regardless of the initial costs, the potential savings discussed in Chapter 2 will quickly pay for the program and meet a 5-year payback deadline.

Table 1. Maintenance costs vs. savings for three Army heating facilities.

	Annual Labor	Annual Materials	Annual Savings	5 Yr Savings
Plant 1	$126,358	$50,440	$9,718	$48,590
Plant 2	54,770	19,131	3,926	19,630
Plant 3	33,400	6,500	1,851	9,255
Cost to Implement Predictive Maintenance: $18,000				
Sources: Stevens; phone conversion with Kenneth Zandler, CECPW-SS-C, March 1993.				

4 Maintenance Management Issues and Tools

After a maintenance program has been chosen, further time and money savings are possible if the program is effectively managed. In the past, the term *maintenance management* has generally been understood to include a computer-based management system. However, for the purposes of this report, any structured maintenance operation is considered a management program. Therefore, either improvements in an existing system or the introduction of computer-based management tools are considered maintenance management. This chapter discusses different methods for improving maintenance management, and presents guidelines for selecting and implementing improved maintenance management programs.

Organizational Skills

The simplest way to improve maintenance management is to improve organizational skills. This improvement may be made manually or aided by computer (or a combination of the two).

Manual improvements address such simple tasks as bookkeeping, work order preparation and logging, and inventory. These tasks are part of maintenance management at every Army central energy plant, but they are not always executed efficiently. The main cost of this improvement is the initial investment of time to establish and begin a more organized system. The time saved as a result of such simple improvements easily makes up for the initial time investment—and the efficiency improvement continues as long as attention is paid to good organization.

Computerized improvements address the same tasks, but with greater speed and efficiency. Instead of generating reports manually, a computer would be used for information processing, storage, and distribution. This approach also requires an initial time investment for implementation and training, but the time savings resulting from improved clerical efficiency and accuracy soon outweigh the initial investment. Obviously, a facility that has no desktop computer would have to invest in a system. The cost for a standard business-quality desktop computer, necessary peripherals (e.g., printer), and basic software application packages may be as much as $2000, depending on the size and needs of the facility. These figures would cover some basic business software, such as a spreadsheet program and a word processor. Many computers now are "bundled" with integrated applications that handle word processing, spreadsheets, and database management.

Maintenance Management Software

The next step up the progression of improvements would be to purchase an off-the-shelf maintenance management software package. These computer programs are specifically designed to automate many maintenance bookkeeping tasks traditionally executed with pencil, paper, and pocket calculator. Because there are so many packages from which to choose, this report splits them into two price groups: under $4000 and over $4000.

Programs costing under $4000 typically perform basic tasks including:

- scheduling maintenance procedures
- printing work orders
- logging work orders
- inventory parts
- inventory labor
- print maintenance reports.

Note that these programs need a facility-specific database to be of benefit. This database can be generated by properly trained facility personnel or by representatives of the software vendors for an additional fee (ranging from about $400 to $800 a day). Most software vendors provide basic training and support for their software, which is often sufficient to enable in-house personnel to generate the database.

The total investment for maintenance management software in this category could run up to $10,000 or more, when the costs of computer hardware, operating software, database development, and thorough employee training are factored in. All of these factors should be considered before purchasing one of these software packages.

The following comparison of all the steps involved in performing a single maintenance task, with and without the aid of a software package, illustrates some typical benefits of maintenance management software. In this example, a worn bearing in a service pump needs to be replaced.

Under the status quo in many facilities, maintenance would not be scheduled until the service pump has failed, or has reached a state of questionable integrity. The following paragraphs provide a simplified explanation of the steps necessary for emergency pump repair under the current system.

First, the full extent of the problem must be identified, usually through machine inspection. However, it is often necessary to obtain approval before taking a machine off-line for inspection. Approval would include tracking down the shift supervisor and obtaining permission, as well as obtaining any special permits required for the procedure. Further complications arise if the machine is critical and no backup unit is available, but in this example, the machine is noncritical.

After the inspection is complete, an outline must be developed to describe the required maintenance procedure. This outline is usually written in the form of a work order, and involves nothing more than a brief written explanation that is filed with the shift supervisor when the task is complete. The work order includes task designation and resource allocation (i.e., what tools and materials are necessary to complete the task). If all necessary materials are not stored at the facility, arrangements must be made with the appropriate vendor to fill the shortage.

The next step is the actual repair process. Repairs are to be carried out according to the work order, with any additional work to be performed as needed. An accurate record should be made for all completed work, as well as a master list of machine condition deficiencies that have arisen since the machine was last serviced. From this list of deficiencies, a new repair schedule should be formulated, and the above repair process repeated as necessary.

If a computerized maintenance management system were being used in this same example, most clerical tasks listed above would be simplified. The software would have automatically scheduled the bearing inspection before machine failure, allowing for replacement at a convenient time instead of forcing an emergency repair situation. Furthermore, the program would list all permits required for the task, as well as all necessary materials and tools. For materials not on hand, the software would also list the vendor's point of contact for each required acquisition. As can be seen, most of the clerical "busywork" has been eliminated through use of maintenance management software.

The example above refers to benefits of software packages in the under-$4000 category. There is also a wide selection of maintenance management software available in the $4000-plus category. The actual tasks performed by each program can vary. Listed below are typical extra capabilities available with some of the more expensive programs:

- inventory transaction logs
- accounting: labor time
- accounting: material cost
- resource balancing
- shutdown/turnaround support
- ad hoc reporting
- user-changeable screens/reports
- on-screen help
- graphics: screen/reports
- telephone support (sometimes at additional cost)
- site visit support (at additional cost).

This is not a complete list of options available in this category of software, but the options are representative of the capabilities that may be purchased. Note that the final cost for some of the higher-end packages could reach $30,000 or more. Considering that most Army central energy plants are relatively small, the more costly applications may not offer the Army a practical payback period: out-of-pocket costs for system acquisition and training may be too high to recover in a reasonable amount of time. Therefore, the discussions that follow are based on the assumption that packages costing less than $4000 would be adequate for the needs of Army central energy plants. The appendix lists vendors offering maintenance management packages in this price range.

Implementing Maintenance Management Software

Regardless of the type of maintenance management software selected, the steps for implementation are similar. In general, the same steps outlined in Chapter 3 for starting a preventive maintenance program should be followed to implement a maintenance management program, but some changes will be necessary.

The predictive maintenance approach described in Chapter 3 focuses on periodic monitoring of rotating equipment with a vibration analyzer. When starting a maintenance management program, *all* maintenance tasks should be included to maximize the benefits of predictive maintenance. Improved management will improve the efficiency of all aspects of predictive maintenance programs.

Update machine maintenance histories continually. Monitoring and updating machine histories promotes a more efficient program by eliminating some unnecessary tasks or adding new tasks to older machines as they become faulty.

Make sure the initial database is complete. If it lacks any necessary information, essential tasks will not be scheduled.

In addition to the employee training needs noted earlier, adequate computer training must be provided for all personnel using the software. The program will not succeed if employees are unable to understand or correctly use the new system.

After implementation, the maintenance management system's progress should be evaluated continually. Most systems must be custom fit for each plant's individual needs. This custom fit may take months—or even years—to evolve, and it relies on feedback from everyone involved in maintenance.

For facilities relying on computerized management tools for the first time, a few words of caution may be helpful:

Do not buy an expensive program assuming that its advanced capabilities will be useful. Most advanced capabilities are useful only to large commercial energy facilities.

Do not assume that computer technology will automatically improve maintenance operations and management. The technology is nothing more than a tool, and its capabilities are limited by the capabilities of the user. The most common reason maintenance management programs fail is staff misunderstanding of how to use the management tools (e.g., computer technology).

Make sure employees know that the purpose of maintenance management technologies is to make their job easier by automating the time-consuming, tedious, repetitive tasks that are, nevertheless, absolutely necessary to good maintenance management. Some resentment has been observed at sites where the employees felt that maintenance management programs were being used to scrutinize their work or evaluate their productivity. While employee skill levels must be known before maintenance tasks can be scheduled, managers should not use these programs as an assessment tool.

Select a maintenance management package that offers adequate customer support. This support can include user's manuals and tutorials, online help, and a telephone support line. However, do not forget that many customer-support options may be available only at extra cost.

Economic Aspects of Improved Maintenance Management

It should not be assumed that establishing and operating a maintenance management program would require extra personnel. Although it may be necessary to hire or train an individual to run the maintenance management program, the improved efficiency of maintenance operations will reduce the amount of time spent on maintenance by the general staff. The net result is a reduction in manhours, which lowers labor costs. Further savings will occur at larger facilities where backup equipment and spare parts are stored. By properly inventorying all excess equipment and parts, employees may avoid unnecessary downtime due to unavailable parts, and unnecessary costs due to overstocking unneeded parts.

To determine which maintenance management software best suits the needs of a particular facility, a brief look at potential savings versus costs will usually make the choice clear. The example below outlines the potential savings for an average Army central heating facility (two full-time maintenance personnel working 5 days a week). The potential savings are calculated on the basis of high and low estimates found in the literature for lost time (e.g., waiting between assignments, unavailable tools or materials, waiting for special permits or inspections, etc.). The estimate for cost savings is based on the industry target of 10 percent productivity improvement after a maintenance management plan is implemented. To determine what type of maintenance management program is cost-effective for a specific facility, a similar type of comparison should be made, and the results should be tabulated as shown in Table 2.

Recalling that the cost for a basic maintenance management program may reach $10,000 after paying for hardware, software, and training, and assuming that actual savings typically fall somewhere in between the two industry estimates for lost time given in Case 1 and Case 2, it can be seen that many facilities would probably meet a 5-year payback deadline. Simply improving organizational skills will yield extra savings for very little additional cost.

Table 2. Maintenance management costs vs savings for an average Army heating facility.

	Daily Lost Time	Daily Labor Cost for Lost Time (@$18/hr)	10% Daily Savings (Goal)	Annual Savings	5 Yr. Savings
Case 1	9 hr*	$162.00	$16.20	$4,212.00	$21,060.00
Case 2	2 hr**	36.00	3.60	$836.00	$4,680.00

*Source: Stevens; Rockwood 1991.
**Estimated as minimum by authors.

5 Summary

One important way for Army central energy plants to reduce operating costs is to improve maintenance operations and management practices. Significant improvements can be achieved by implementing a preventive or predictive maintenance program, and by improving organizational and managerial skills. After the initial costs of establishing such a program are paid back through improved plant efficiency, lower maintenance costs, and less downtime, the benefits continue indefinitely in the form of hard savings.

Almost all Army central energy plants could meet a 5-year payback deadline by implementing a preventive maintenance program. For the many facilities that can afford the higher initial costs of implementing a predictive maintenance program, a 5-year payback is also reasonable to expect.

All Army energy facilities can become more efficient by improving maintenance management practices, such as applying better organizational skills or computerizing routine recordkeeping tasks. For many facilities, a properly selected off-the-shelf maintenance management software package will pay for itself in 5 years if proper attention is given to training system users.

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Appendix: Maintenance Management Packages Costing Under $4,000

(Source: Quinn, February 1991)

Company Name	Product Name	Address	Phone Number
Analysis & Technology	Maintenance Management System	190 Governor Winthrop Blvd. New London, Ct 06320	203-443-1180
Anawan Computer Services	PM-Status II	19 Winterberry Lane Rehoboth, MA 02769	508-252-4537
Automation Technology Inc.	Computation	5280 W. 74th St. Edina, MN 55439	612-831-3331
Bender Engineering, Inc.	MaintStar	3535 Farquhar Ave., Suite 2 Los Alamitos, CA 90720	213-598-4741
Business Solutions, Inc.	Maintenance Manager	837 Chicago Ave. Evanston, IL 60202	708-836-7728
Candlewood Computer Services	PMaint	4 Oakwood Dr. New Fairfield, CT 06812	203-746-1181
Centaurus Software Inc.	Argusnet	4425 Cass St., Suites A-I San Diego, CA 92109	619-270-4552
Chum Software, Inc.	WOPM	P.O. Box 1333 Basalt, CO 81621	303-927-3515
CK Systems	MaintiMizer	772 Airport Blvd. Ann Arbor, MI 48108	313-665-1780
Creative Management	CAMS-3L and CAMS-SQL	400 Riverside Ave. Jacksonville, FL 32202	800-874-5554
dB Micro Systems, Inc.	EPICS	5120 Campbell Suite 110 San Jose, CA 95130	408-374-1661
Decision Dynamics Inc.	DynaStar II and MicroStar	696 McVey Ave. Lake Oswego, OR 97034	503-636-4310
Decision Systems Inc.	MMS	1089 Third Ave. SW P.O. Box 432 Carmel, IN 46032	317-846-1833
Diagonal Data Corp.	Caliper	P.O. Box 2242 Lakeland, FL 33806	813-366-2330

Company Name	Product Name	Address	Phone Number
DP Solutions	PMC/Uptime	207-MS. Westgate Dr. Greensboro, NC 27407	919-854-7700
Eagle Technology Inc.	Expert Maintenance Management	10500 N. Port Washington Rd. Mequon, WI 53092	800-523-9131
Ambrose Frederic Ltd.	StarFax 3.10	350 Rathburn Rd. W. Mississauga, ON L5B 3Y2 Canada	416-949-9875
General Energy Technologies	PMCS	250 E. 17th St. Costa Mesa, CA 92627	714-645-7733
Hansen Software, Inc.	Plant Maintenance Management	1745 Markston Rd. Sacramento, CA 95825	916-921-0883
Frank Herbaty and Associates	Cost-Effective Maintenance Management	253 Plainview Dr. Bolingbrook, IL 60440	708-759-1915
J&H Software Inc.	Maintenance Manager/Equipment	2000 W. Central Ave. Toledo, OH 43606	419-473-9611
Josalli Inc.	Preventive Maintenance System	P.O. Box 460 Enka, NC 28728	704-252-9146
M^2 Ltd.	Mainplan E/Q	9210 Witchman Rd., Suite 300 Gaithersburg, MD 20879	301-977-4281
Macola Inc.	Operator 10	333 E. Center St. P.O. Box 485 Marion, OH 43301	800-468-0834
Management On-Line, Inc.	Maintenance Management System	6301 Hollister, Suite 110 Houston, TX 77040	713-690-0697
Minneapolis Software, Inc.	PM Manager	2499 Rice St. Roseville, MN 55113	612-484-5684
Nanosoft	Prefix	7575 San Felipe, Suite 325 Houston, TX 77063	713-266-6266
Omni Software Systems, Inc.	Preventive Maintenance System	146 Broad St. Griffith, IN 46319	219-924-3522
OmniComp, Inc.	Service Call	220 Regent Ct., Suite E.P.O. Box 332 State College, PA 16804	800-726-4181
Owen Engineering & Management	Turbo Maintenance Manager	5353 W. Dartmouth Ave. Suite 407 Denver, CO 80227	303-969-9393
Panda Software	PM Plus	The Atrium, Suite 226 10400 Linn Station Rd. Louisville, KY 40223	800-537-1694

Company Name	Product Name	Address	Phone Number
Penguin Computer Consultants	Maintenance and Inspection	P.O. Box 20485 San Jose, CA 95160	408-997-7703
Peregrine Systems	OOPS! Ounce of Prevention System	1638 Pinehurst Ct. Pittsburgh, PA 15237	800-852-8075
Peters & Co.	MainMan	80 N. Main St. Zionsville, IN 46077	317-873-0086
Phoenix Data Systems, Inc.	AIMS Basic Core	24293 Telegraph Rd. Southfield, MI 48034	313-358-3366
Project Services International	T.I.M.M.	Robinson Plaza 3, Suite 300 Pittsburgh, PA 15205	412-747-0111
PSDI, Project Software & Development, Inc.	Maximo Maintenance System	20 University Rd. Cambridge, MA 02138	617-661-1444
Rambow Enterprises	Maintenance Management	15127 NE 24th St., Suite 152 Redmond, WA 98052	206-881-7243
SAS Institute, Inc.	SAS/OR	SAS Campus Drive Cary, NC 27513	919-677-8000
Specific Design, Inc.	EM/dBS	21062 Brookhurst St. Suite 103 Huntington Beach, CA 92646	800-262-8988
Team Tech Systems	Team Maintenance Management System	127 Michael Dr. Red Bank, NJ 07701	908-530-1805
Timesaver Systems	CMMS/Phase 1	4732 NE 103rd Portland, OR 97220	503-253-0098
Transpower Corp.	Optimal Manager	One Oak Drive Parkerford, PA 19457	215-495-6362
Unique Computer Systems	MVP	455 W. LaCodena, Suite 14 Riverside, CA 92501	714-683-3723

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